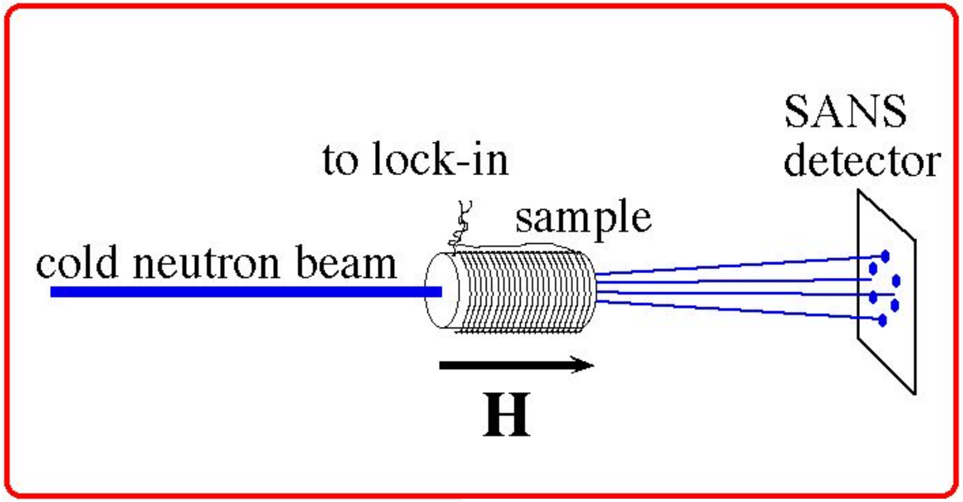
Novel Studies of Vortex Matter and Peak Effect using *in-situ* Neutron Scattering and AC Magnetization

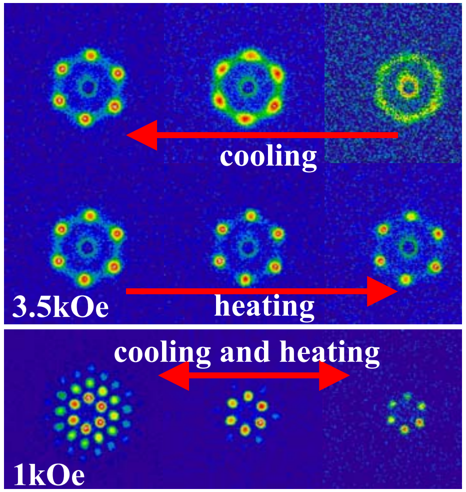
Sean Ling (PI), Brown University, DMR-0102746

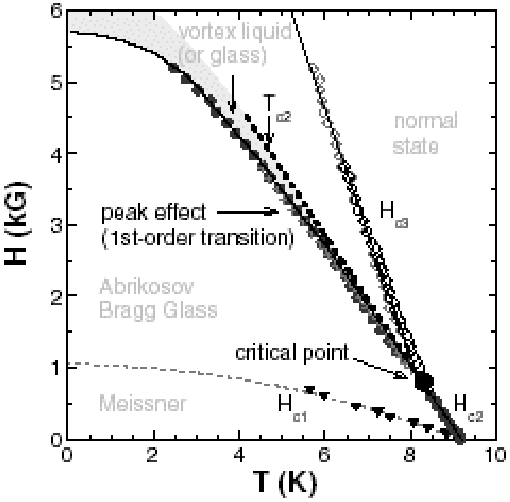
Type-II superconductors such as Nb, NbTi, Nb_3Sn and high-temperature superconductors are important for applications such as MRI and power transmission. The ability of type-II materials to carry supercurrent is determined by the pinning of Abrikosov (2003 Nobel Prize winner) vortices. A longstanding question in vortex physics is why many type-II superconductors show a peak effect in critical current near upper critical field. Is it a phase transition in the vortex matter? What is the nature of the phase transition?

Using a combined neutron scattering and magnetization technique, we found direct evidence [1] for an order-disorder (melting) transition in the vortex matter at the peak effect, as well as a multicritical point in the phase diagram [2]. The new phase diagram shows a mean-field transition at low field (predicted by Abrikosov), and a first order melting transition at high field (not predicted by Abrikosov, but suggested by the recent Bragg-glass theory).

Figure: (Upper panel): Brown-NIST experimental configuration; (Lower-left): hysteresis in vortex-matter structure factor S(Q) at 3 kOe (upper), and reversible S(Q) at 1 kOe (lower panel). Implication: a critical point on the field-temperature phase diagram separating 1st order and 2nd order transitions (lower-right).







Publications supported by this grant:
[1] X.S. Ling et al., Physical Review Letters **86**, 712 (2001).
[2] S.R. Park et al., Physical Review Letters **91**, 167003 (2003).
[3] S.R. Park et al., (in preparation, 2003).

Education: The NSF grant supported fully or partially three Ph.D. students at Brown: S.R. Park (5th yr.), I. Dimitrov (4rth yr.), N. Daniilidis (2nd yr.) and undergraduate student Bridget McClain (Sc.B.'04).

In the photo below, Ph.D. student Sang Ryul Park and undergrad Bridget McClain are transferring liquid helium into the cryostat with the assistance from NIST scientist Jeff Lynn and the PI at the NIST facility.

New research activities launched:
During the past year, the PI started a feasibility study of using ultrasound attenuation technique to study the peak effect problem. The motivation is to gain a deeper understanding into the disordered vortex phase just above the peak effect where neutron scattering signal is too weak to resolve the dynamics and the ac magnetic field cannot penetrate into the bulk of the sample due to surface current. We found encouraging preliminary evidence suggesting that ultrasound attenuation is effective in addressing some of the key issues concerning the disordered phase, due to the fact that ultrasound can penetrate into the bulk of the sample.

This activity will be continued in the next funding period as outlined in the renewal proposal.